North Dakota Water Resources Research Institute
Annual Technical Report
FY 2011

Introduction

INTRODUCTION

This report describes the activities of the North Dakota Water Resources Research Institute (NDWRRI) during the period of March 1, 2011 to February 29, 2012.

The ND WRRI is one of the 54 institutes known collectively as the National Institutes for Water Resources (NIWR). The NDWRRI was founded in 1965, by authority of Congress (Water Resources Research Acts of 1964, 1972, 1984, and 1990), and is administrated through the United States Geological Survey. Section 104 of the Water Resources Research Act requires the NDWRRI to apply its Federal allotment funds to:

1. Plan, conduct or otherwise arrange for competent research that fosters: (A) the entry of new research scientists into the water resources field, (B) training and education of future water resources scientists, engineers, and technicians; (C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena; and (D) the dissemination of research results to water managers and public.

2. Cooperate closely with other college and universities in the state that have demonstrated the capability for research, information dissemination and graduate training, in order to develop a statewide program designed to resolve State and regional water and related land problems.

3. Cooperate closely with other institutes and other organizations in the region to increase the effectiveness of the Institute and for the purpose of promoting regional cooperation.

This year, NDWRRI once again allocated its 104(B) resources to fund Graduate Fellowship research projects. The institute also continued its efforts to enhance communications between the State and Federal agency personnel and university faculty and students. NDWRRI also worked closely with the Environmental and Conservation Sciences program of North Dakota State University (NDSU), Natural Resources Management program of NDSU, and the International Water Institute, Fargo, ND on water related research issues and collaboration.

Program Management

The Institute continued the same administrative mechanism with a director managing the institute program with the help of a State Advisory Committee. Dr. G. Padmanabhan, Professor of Civil Engineering, is the director. Linda Charlton, a NDSU employee, has been working part-time for the Institute to assist the director with Institute finances, communications and information transfer. The State Advisory Committee consists of three members representing the three principal water agencies in North Dakota: State Water Commission, State Department of Health, and the USGS North Dakota District. In addition, the Institute also seeks advice from the faculty of the two research universities of the State: North Dakota State University and University of North Dakota.

State Appropriation

The State Water Commission continued its support of 15% match to the 2011 2012 the Graduate Research Fellowship program of NDWRRI under federal 104 (B) funding. This is eighth year the SWC provided support to the Fellowship program.

University Support

North Dakota State University and the University of North Dakota administrations consider the NDWRRI activities important and are supportive of its efforts.

Institute Location

The Institute continues to operate from the Administrative Building of the College of Engineering and Architecture of North Dakota State University in Fargo, North Dakota, The director may be reached at:

ND Water Resources Research Institute North Dakota State University Civil Engineering, Dept. # 2470 Fargo, ND 58108-6050 Phone: (701) 231-7043 Fax: (701) 231-6185 E-mail: G.Padmanabhan@ndsu.edu

State Advisory Committee

The State Advisory Committee provided guidance on water resources research priorities in the State and region, and participated in the review and evaluation of research proposals and projects. The current committee members are:

Gregg Wiche, District Chief, U.S. Geological Survey, Water Resources Division, Bismarck, North Dakota

William Schuh, Water Appropriation Division, North Dakota State Water Commission, Bismarck North Dakota

Mike T. Sauer, Environmental Health Section, North Dakota Department of Health, Bismarck, North Dakota

The committee members are senior officials in the three major agencies in North Dakota responsible for much of the water resources research done outside of NDSU and UND in North Dakota.

Research Program Introduction

RESEARCH PROGRAM

ANNUAL BASE GRANT (104-B)

In the past several years NDWRRI has offered competitive fellowships to NDSU and UND graduate students for research on water resources topics under a Graduate Research Fellowship (GRF) program effectively using the modest amount of the 104(B) annual base grant. The program meets the requirements of Section 104 of the Water Resources Research Act of 1984. The fellowship program encourages entry of young university faculty and new research scientists into the water resources field; provides training and education to future water resource scientists and engineers; promotes exploration of new ideas that address water problems or expand understanding of water quantity, quality and related phenomena; and engages university faculty in collaborative research programs seeking supports from entities concerned with water problems

This year, the NDWRRI continued the GRF program and applied bulk of the federal allotment to it. The GRF program is administrated and monitored by the director. Applications are invited from the graduate students and their advisors of the two research universities of the State, NDSU and UND. A rigorous review by the State Advisory Committee and other water professionals in the state determines the awards. Active participation of the academic advisors of the students in meeting matching requirement and seeking co-funding from local, state and other sources is another positive aspect of the program. Periodical review of the progress of the students in meeting the fellowship expectations is ensured by seeking reports from the students and by encouraging them to make presentations in local, regional, and national technical seminars and conferences.

Guidelines for the 2011-2012 Graduate Research Fellowship were posted on the Institute website in September 2010, and the request for applications was announced in the faculty news publications of the two university campuses in last week of October. The following is the request for application that was published on the UND and NDSU campus newsletters, and distributed by e-mail lists:

September 25, 2010 Issue of It s Happening at State (NDSU Publication). An nnouncement similar in content was also published in the University of North Dakota campus publication University Letter

2011 ND WRRI graduate research fellowship applications invited

The North Dakota Water Resources Research Institute (ND WRRI) has announced its 2011 Graduate Research Fellowship program.

North Dakota State University and University of North Dakota graduate students who are conducting or planning research in water resources may apply for fellowships varying from three summer months to a full year in duration. Typically in the past fellowship awards for master's degree students have been in the range $800-$1,000 and for doctoral students it has been $1,000-$1,400 per month. The fellowship funds must be applied between March 1, 2011, and Feb. 29, 2012.

Projects proposed for fellowship support should relate to water resources research issues in the state or region. Regional, state or local collaborations or co-funding will strengthen an application. Fellowships have a matching requirement of two non-federal dollars to one federal dollar. At the time of applying, applicants should have a plan of study filed and/or should have a thesis research topic selected. Applications need to be prepared in consultation with advisers. Advisers of the applicant should co-sign the applications. Applications from students and advisers who have not met the reporting requirements of their previous fellowship projects

will not be considered for funding.

The general criteria used for proposal evaluation include scientific merit, originality of research, research related to state or region, and extent of regional, state or local collaboration and/or co-funding.

Applications are due in the office of the ND WRRI director by 5 p.m., Nov. 12. The proposals will be reviewed by a panel of faculty members and state water resources research professionals. Announcement of awards will be made by early January. Consult the ND WRRI Web site, www.ndsu.edu/wrri, for background information on the program, and guidelines for preparation of applications. Applicants and advisers who are new to the program are urged to contact ND WRRI director, G. Padmanabhan, at 1-7043, or G.Padmanabhan@ndsu.edu.

Send applications to Dr. G. Padmanabhan, Director of North Dakota Water Resources Research Institute, Civil Engineering, CIE 201E, NDSU Department 2470, P.O. Box 6050, Fargo, ND 58108-6050.

NDWRRI GRADUATE RESEARCH FELLOWSHIPS

Fellowships ranging from $2000 to $12,000 were awarded to nine graduate students from NDSU conducting research in water resources areas from 104(B) funding. Additionally three students each from NDSU and UND were awarded Fellowships from ND State Water Commission support of the Fellowship program. NDSWC funding was also used for partially enhancing the Fellowship amounts. Selection of student Fellows and the award amounts were based on competitive proposals prepared by the students with the guidance of their advisers. Projects proposed for fellowship support should relate to water resources research issues in the state or region. Regional, state, or local collaboration or co-funding is encouraged. Fellowships have a matching requirement of two non-federal dollars to one federal dollar. A panel of state water resource professionals reviews the proposals and selects the Fellows and award amounts based on the quality of proposals and the priority of the proposed projects for the state and region. The general criteria used for proposal evaluation include: scientific merit, originality of research, research related to state and/or region, and extent of regional, state or local collaboration and/or co-funding.

This year, fifteen applications were received: eight Ph.D. and seven MS students. Highly competitive proposals and limited availability of funds restricted the amount of awards. Four of the Fellowships were renewals, three Ph.D and one MS. The renewals are Brianna Schneck, Anusha Balangoda, Dhritikshama Roy, and Andrea Hanson.

The titles of the 104 (B) and NDSWC fellowship projects awarded are given below and details of only 104 (B) Fellowship projects are provided for each project under separate project sections.

2011-12 ND WRRI Fellows, their advisers, and Fellowship research projects:

Andrea Hanson (Fellow), Biological Sciences; Mark Sheridan (adviser); NDSWC Uptake and effects of environmental estrogens on growth of fish

Anusha Balangoda, Environmental and Conservation Sciences; Wei Lin; 104B Studies of Seasonal Succession of Cyanobacteria and Green algae at Heinrich-Martin Impoundment, North Dakota

Brianna Schneck, Biological Sciences; John McEvoy and Mark Clark; 104B Source tracking of Cryptosporidium in rural watersheds

Christopher Capecchi, Civil Engineering; Achintya Bezbaruah; 104B Arsenic Contaminated Groundwater Remediation by Entrapped Nanoscale Zero-Valent Iron

Dhritikshama Roy, Civil Engineering; Achintya Bezbaruah and Eakalak Khan; 104B Plant-based Biopolymers for Entrapping Metal Nanoparticles for Arsenic Removal: Biodegradation and Treatability Studies

Hasin Shahad Munna, Civil Engineering (UND); Howe Lim; NDSWC Flood Risk Assessments of Various Scenarios for Devils Lake under GCM Downscaling Simulations Using a Coupled Hydro-Climatic Model Incorporating Recent Advances in Lake Evaporation Estimations.

Justin Fisher, Biological Sciences; Craig Stockwell; NDSWC Integrating life stage habitat into landscape genetics model for the conservation of a declining amphibian species

Kate Overmoe-Kenninger, Earth Science System and Policy (UND); Xiaodong Zhang; NDSWC Assessment of Water Quality in Devils Lake using Satellite Imagery

Katrin Chambers, Soil Science; Francis Casey; 104B Bioavailability of Dissolved and Colloidal Organic Carbon Bound Estrogen

Kyle Hafliger, Civil Engineering (UND); Howe Lim; NDSWC Techniques of Assessing Changes in River Flooding Patterns

Lindsey Malum, Natural Resources Management; Edward Dekeyser and Jack Norland; 104B Ecosystem Services and Wetland Condition Assessment in the Prairie Pothole Region

Mohammed Mizanur Rahman, Ag. and Biosystems Engineering; Zhulu Lin; NDSWC Hydrologic adaptation of SWAT model for snow dominated and high groundwater table conditioned watersheds and scenario analysis of impacts of tile drainage on stream flow

Sharanya Shanbhogue, Civil Engineering; Achintya Bezbaruah and Eakalak Khan; 104B Co-entrapment of iron nanoparticles and trichloroethylene degrading bacteria in alginate biopolymer for groundwater remediation

Tanush Wadhawan, Civil Engineering; Eakalak Khan and John McEvoy; 104B and NDSWC Role of agricultural drainage on transport of Cryptosporidium oocysts in North Dakota

Veselina Valkov, Civil Engineering; Wei Lin; 104B Temporal-spatial distribution (dynamics) of phytoplankton and diversity in relation to lake physical and chemical condition

NATIONAL COMPETITIVE PROGRAM (104-G)

Two proposals were submitted; but were not funded:

Does the Longitudinal Profile and Distribution of Stream Power Affect the Efficiency and Ecology of Agricultural Drainage Ditches? by Phil Gerla, Department of Geology and Geological Engineering, University of North Dakota

Impacts of Land-use Change on Environmental and Water Quality in the James River Basin: Predicting Economic and Physical Outcomes for Efficient Policy Making by Robert Hearne and Zhulu Lin, Agricultural Economics and Agribusiness, North Dakota State University

Source tracking of Cryptosporidium in rural watersheds

Basic Information

Title:	Source tracking of Cryptosporidium in rural watersheds
Project Number:	2009ND183B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	1
Research Category:	Biological Sciences
Focus Category:	Water Quality, Surface Water, Non Point Pollution
Descriptors:	
Principal Investigators:	John McEvoy, Mark Clark

Publications

1. Schneck, B.L., Pennil, C.C., Lanctot, V.T., Giddings, C.W., Clark, M.E., and McEvoy, J.M. 2009 Cryptosporidium genotypes in Midwestern mammals Poster presented at III International Giardia and Cryptosporidium Conference, Orvieto, Italy, Oct.11-15, 2009.
2. Pennil, C. C., Clark, M.E., Schneck, B.L., Giddings, C.W., and McEvoy, J.M. 2009. High prevalence of Cryptosporidium andersoni in surface water during a major spring flooding event Poster presented at III International Giardia and Cryptosporidium Conference, Orvieto, Italy, Oct.11-15, 2009.
3. Pennil, C.C., Clark M.E., Giddings C.W., Schneck B.L., and McEvoy J.M. 2009. Determining sources of Cryptosporidium in a rural watershed. Master s Thesis (Chapter 2), North Dakota State University, Fargo, North Dakota, Chapter 2.
4. Stenger, B.L., Pennil, C. C., Clark, M.E., Lanctot, V. , Giddings, C.W., and McEvoy, J.M. 2010 Cryptosporidium transport in the Red River Valley during major spring floods North Dakota State EPSCoR Conference, Grand Forks, ND, 2010.
5. Schneck, B.L., Pennil, C. C., Clark, M.E., Lanctot, V. , Giddings, C.W., and McEvoy, J.M. 2010 Cryptosporidium transport in the Red River Valley during major spring floods Summer COBRE poster presentation in Fargo, ND, 2010.
6. Schneck, B.L., Pennil, C.C., Lanctot, V.T., Giddings, C.W., Clark, M.E., and McEvoy, J.M. 2010 Cryptosporidium genotypes in Midwestern mammals Updated poster presented at the 7th Northern Plains Biological Sciences Symposium in Fargo, ND, 2010.

The Upper Midwest has among the highest incidences of human cryptosporidiosis in the U.S. There is therefore a critical need to determine Cryptosporidium sources and transmission dynamics in this region. A study, which I co-authored, has shown that most human cryptosporidiosis in the region is caused by C. parvum, a species associated with humans and cattle. However, the traditional model, describing Cryptosporidium movement from livestock to humans via water, appears over simplistic in light of recent evidence of wildlife sources of contamination. To better understand the human health significance of Cryptosporidium in rural watersheds, we need to determine the source of the contamination.

The objective is to determine the factors influencing the contributions of cattle and wildlife to Cryptosporidium in rivers. This is critical to understand the public health significance of Cryptosporidium in rural watersheds.

Empirical evidence supports host adaptation and a limited host range for most Cryptosporidium species and genotypes. This knowledge has been used to track sources of water contamination and characterize human health risk; however, the factors affecting host range remain unclear. We are using small mammals (mainly rodent species) as a model to study the effect of factors such as host population density, diversity and behavior on the host range of Cryptosporidium genotypes.

Spring flooding results in the movement of Cryptosporidium from the fields of North Dakota, South Dakota and Minnesota to the Red River. Livestock contributed significantly to Cryptosporidium contamination in the Red River during major spring floods. Cattle were the primary source of surface water contamination. We can estimate the flow of oocysts during peak flooding in 2010 at 728,000 per second, based on our oocyst counts and a river flow of 560,000L per second. That is significant when it can take less than 100 oocysts to infect a host.

Small mammals are hosts to various genotypes of Cryptosporidium. We found Cryptosporidium species or genotypes in over 42% of our samples. We now have more than 600 samples and the prevalence is approximately 40%. We've identified at least 14 Cryptosporidium genotypes/species in 10 wildlife host species. We have found a novel genotype of Cryptosporidium in Eastern chipmunks and are planning to publish the findings once further molecular characterization and microscopic analysis is complete. Two species of Cryptosporidium, C. parvum and C. ubiquitum, are considered human pathogens, and were found in a number of wildlife samples.

Studies of Seasonal Succession of Cyanobacteria and Green algae at Heinrich-Martin Impoundment, North Dakota

Basic Information

Title:	Studies of Seasonal Succession of Cyanobacteria and Green algae at Heinrich-Martin Impoundment, North Dakota
Project Number:	2011ND237B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	01
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Nutrients
Descriptors:	None
Principal Investigators:	Wei Lin

Publications

1. Anusha Balangoda (2011) Impact of Eutrophication on Water Quality at Heinrich-Martin Dam Impoundment, North Dakota , Young Professionals poster competition at the North Dakota Water & Pollution Control Conference (NDWPCC), 11-13 October 2011, Bismarck
2. Anusha Balangoda (2011) Population Variation of Cyanobacteria and Green Algae at Heinrich-Martin Dam Impoundment, ND , Presented at the 5th International Student Prairie Conference, June 2-3, 2011. North Dakota State University, Fargo, ND.
3. Anusha Balangoda, Veselina Valkov, Jinhai Zhao, and Wei Lin (2012) Seasonal Variations of Water Quality and Algal Growth in the Heinrich-Martin Dam Impoundment Presented at the North Dakota Water Quality Monitoring Conference, February 27-29, Bismarck, North Dakota.

In North Dakota, major industry is agriculture including production of many crops, farms, and ranches. So the major sources of nutrients (Nitrogen and Phosphorous) loading into the ND's lake and reservoirs are erosion and runoff from animal feeding operations, and hydrologic modifications. So this excessive level of phosphorous and nitrogen may result in an overstimulation of nuisance algal blooms. According to the seasonal variation when lakes become more eutrophic, with the increase of phytoplankton biomass the diversity of the assemblage decreases ultimately leading to the dominance of cyanobacteria (Blue green algae). Blue-green algal blooms (Harmful Algal Blooms-HABs/Cyanobacteria blooms) produce toxins are poisonous to animal and human health in waters used for recreational and drinking purposes. So in contrast to other phytoplankton, cyanobacteria can withstand under wide range of environmental conditions which is related to their specific growth characteristic features. So eutrophication is not only being a state wise problem it is one of the most widespread environmental problems of inland waters in the world.

The main objective of this study is to identify population variation of cyanobacteria and green algae in relation to their growth requirements.

Impacts of Aeration on the Water Temperature & the Dissolved Oxygen (DO)

Seasonal variations of water temperature and DO were observed in 2010 and 2011. In addition to seasonal variation, thermal stratification was observed after aeration was turned off for a month in 2011. Thermal stratification was established only in the deeper part of the impoundment after aeration was turned off. When the aeration was in operation the lake showed a mixed condition. The water temperature difference from surface to bottom of the water column was less than 0.5˚C (Fig. 1a). DO also showed pronounce vertical variation along the depth. A rapid DO drop from surface (7 mg/L) to 2 m (1 mg/L) was observed after aeration was turned off. The DO concentration less than 1 mg/L was observed near the bottom in the deeper part of the impoundment over the stratified period.

Impacts of Aeration on Nutrient Concentrations

Nitrogen (N) and phosphorous (P) are the nutrients that limit plant and algae growth. TDIN (NH_4^+, NO_3^-, and NO_2^-) and SRP (soluble reactive phosphorous) are the available forms for algal growth. Both TDIN and SRP showed seasonal variations during sampling in 2010 and 2011. In addition to seasonal variation, variations of nutrients concentration with the condition of aeration and after the aeration was turned off were also observed. Nutrients were mostly distributed from surface to bottom in the lake when the aeration was in operation. However, when the aeration was turned off, nutrients concentration varied along the depths in deeper part of the impoundment. The SRP concentration showed concentration gradient from surface (0.06 mg/L) to bottom (0.45 mg/L) may indicate release of phosphorous from sediment to overlying water column (Fig. 2a). Similar to SRP, the TDIN concentration also showed concentration gradient from surface (0.08 mg/L) to bottom (1.1 mg/L). The TDIN concentration was dominated by NH_3-N near the bottom (1.08 mg/L) shows that possible release of NH_3-N from sediment to water column. Further, results showed that N and P concentration gradient from surface to bottom was significant in HMD over the stratified period. Therefore, the mechanisms and factors that affecting release of nitrogen and phosphorus from sediments to water column is needed to be studied in HMD.

The TDIN: SRP ratio varied seasonally as well as under the condition of aeration and after the aeration was turned off during sampling in 2010 and 2011.The TDIN: SRP ratios changed from 6.44:1(with aeration) to below 2:1 (without aeration), which was less than the cellular element mass ratio (7.2:1) of algae, indicates N limiting condition in HMD (Fig. 2c). Therefore, the factors that affecting for N limitation is needed to be determined in HMD. Further, results showed that total phosphorous (TP) concentration was ≥100 µg/L in HMD. Limnologist and lake managers predict nuisance algal blooms with TP concentration greater than about 0.01 mg/L (Gibson et al., 2000). Therefore, determination of what causes P rich condition in HMD is also needed.

Impacts of Aeration on the Chlorophyll a (Chl a) Concentration

Chl a is the primary photosynthetic pigment, so a measure of its concentration in a water sample is represent total algal biomass. Chl a showed a seasonal variation over the study period in 2010 and 2011. Under the condition of aeration, Chl a concentration was mostly homogenized throughout the water column. However, there was a significant vertical variation of Chl a was observed in deeper part of the impoundment after the aeration was turned off about a month in 2011. Chl a showed a high concentration (>80 µg/L) from surface/Secchi depth level to a low concentration (<10 µg/L) near the bottom over stratified period. The seasonal stratification of water columns determines the general availability of the resources light and nutrients for phytoplankton growth. Results showed that N and P were accumulated near bottom. Therefore, nutrients may not have adequate supply to a well-mixed top layer after the aeration was turned off. So, what determines their vertical distribution in stratified water columns in HMD are needed to be studied. In addition to Chl a, Secchi depth also measures trophic status in lakes. The Secchi depth showed a seasonal variation over the study period and Secchi depth was ≥ 1 m over most of the sampling dates. The lowest Secchi depth (0.7 m) was observed after the aeration was turned off.

Impacts of Aeration on the Phytoplankton Population

Seasonal variation of phytoplankton population shift was observed during sampling in 2010 and 2011. In addition to seasonal variation, phytoplankton population shift under the condition of aeration and after the aeration was turned off also observed. Algal bloom condition (2.88 × 106 Cells L-1) was observed in HMD when aeration was in operation. Surface water showed green color balls like aggregates and those were identified as Aphanizomenon sp. clusters under inverted microscope analysis. After a week when aeration was turned off, large balls like aggregates showed more dispersed condition and concentrated into the surface layer. A significant decrease of cyanobacteria cell densities (from 4.58 × 106 cells L-1 to 1.14 × 105 Cells L-1) were observed at the surface layer over the stratified period. A Cyanobacteria population, which represented much of the total phytoplankton population, was dropped significantly after the aeration was turned off.

Arsenic Contaminated Groundwater Remediation by Entrapped Nanoscale Zero-Valent Iron

Basic Information

Title:	Arsenic Contaminated Groundwater Remediation by Entrapped Nanoscale Zero-Valent Iron
Project Number:	2011ND238B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	01
Research Category:	Water Quality
Focus Category:	Water Quality, Groundwater, Treatment
Descriptors:	None
Principal Investigators:	Achintya Nayan Bezbaruah

Publication

1. Capecchi, C.; Bezbaruah, A. Novel Alginate Entrapped Nanoparticles for Groundwater Arsenic Remediation, Proc. World Environmental and Water Resources Congress 2011, pp. 3389-3395, 2011 (also oral presentation).

In response to the significant threat arsenic presents, the United States Environmental Protection Agency (USEPA) drastically modified the maximum contaminant level (MCL) for arsenic in drinking water from 50 µg/L to 10 µg/L in 2006. Even at 10 µg/L the world health organization (WHO) estimates a 0.2% chance of developing cancer in humans. Millions are presently at risk due to high arsenic levels in drinking water. Acute and chronic arsenic exposure from drinking water has been reported in many countries, most of which have large proportions of drinking water contaminated with high concentrations of arsenic (total As 50 µg/L). The United States Geological Survey (USGS) analysis of 30,000 random groundwater samples across the United States found that approximately 10% of sites had arsenic concentrations in excess of 10 µg/L.

Moreover, arsenic is second only to lead (Pb) as the most commonly found hazardous contaminant at Superfund Sites. In Southeastern North Dakota more than 25% of groundwater samples contain arsenic at levels in excess of 10 µg/L. The U.S. EPA conducted a five year review (2004-2008) to analyze the remedial action implemented in Southeastern North Dakota. Approximately 375 wells in the 26 townships (about 568 square miles) were sampled and it was found that more than 84% samples have the arsenic concentration above the MCL. This presents an unacceptable risk of cancer and adverse health effects to the residents who depend upon water from the aquifer. By entrapping NZVI within a biopolymer (Ca-alginate) the overall contact time with contaminants will be prolonged, allowing individual particles to react more efficiently. By optimizing critical parameters such as NZVI dosage and pH, the waters can be effectively remediated below the USEPA arsenic MCL (10 µg/L). The objective of this research is to determine the treatability of arsenic by entrapped NZVI. The specific objectives of the study are: 1) Conduct entrapped NZVI treatability batch studies with various As5+ and As3+ concentrations. 2) Examine the effects of individual ions (which are present in groundwater) on the arsenic removal (by entrapped NZVI) reaction kinetics. 3) Characterize entrapped NZVI within Ca-alginate beads using X-ray diffraction (XRD) and scanning electron microscopy (SEM) to understand the arsenic treatment mechanisms. 4) Perform entrapped NZVI treatability batch studies with actual arsenic contaminated groundwater.

This project explored aqueous arsenic removal using nanoscale zero-valent iron (NZVI) entrapped in calcium (Ca) alginate beads. The results from this study show great promise for entrapment technique as an advanced treatment technique for aqueous arsenic. Arsenic is a serious threat to human health and millions of people are affected by arsenic contamination in various parts of the world including the United States. The entrapment process reduces mobility of the nanoparticles by confining them within the polymer matrix and, thus, reducing the risk of post-treatment hazard by arsenic sorbed onto NZVI. Ca-alginate polymer is an excellent choice as an entrapment medium as it is non-toxic and has little solubility in water. In bench scale batch studies with initial As(V) concentrations of 1-10 mgL-1, ~ 80-100% arsenic removal was achieved within 2 hours. While the reaction kinetics differ between bare and entrapped NZVI, the overall reductions of arsenic are comparable. Surface normalized arsenic reduction reaction rate constants (ksa) for bare and entrapped NZVI were 3.40-5.96x10-3 and 1.90-4.43 x10-3 L m-2 min-1, respectively.

Graduate student who originally worked on this project was Christopher Capecchi, and later two other graduate students and a few undergraduate students participated in this project. One peer reviewed paper (2011) has been published in the Proceedings of ASCE-EWRI World Environmental and Water Resources Congress 2011, and another paper has been submitted (2012) to a referred journal for possible publication. In addition two posters were presented on the research (both in 2010).

Plant-based Biopolymers for Entrapping Metal Nanoparticles for Arsenic Removal: Biodegradation and Treatability Studies

Basic Information

Title:	Plant-based Biopolymers for Entrapping Metal Nanoparticles for Arsenic Removal: Biodegradation and Treatability Studies
Project Number:	2011ND239B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	01
Research Category:	Water Quality
Focus Category:	Water Quality, Methods, Treatment
Descriptors:	None
Principal Investigators:	Achintya Nayan Bezbaruah, Khan Eakalak

Publication

1. Roy, D.; Kalita, H.; Khan, E.; Bezbaruah, A. Fate of Polymeric Nanoparticle Delivery Vehicles in the Aquifer: Biodegradation of Polydimethylsiloxane, 2011 World Environmental & Water Resources Congress, Environmental & Water Resources Institute, American Society of Civil Engineers, Palm Springs, CA, May 2011.

Nanoscale zero-valent iron (nZVI) particles have been attractive for remediation of various contaminants including arsenic. However, because of the smaller particle size and relatively higher dispersibility, nZVI becomes mobile in aquifers. Moreover, in higher concentration, nZVI tend to agglomerate due to magnetic and Van der Waals forces. This allows them to form large particle and settle into aquifer media pores. Agglomerated particle has decreased specific surface and hence lose the reactivity that individual nZVI has.Polymers are used to coat or entrap nZVI to overcome the problem of agglomeration or uncontrolled dispersion, Such entrapped nZVI have shown higher reactivity towards contaminants. However, polymers synthesized in previous research are not biodegradable or shows limited biodegradation. Lack of biodegradation may limit the use of these polymers in groundwater where polymers may themselves become pollutants. It is imperative to development and use polymers which are easily biodegradable to benign end product in the aquifer. This project proposes to use plant-based (bio) polymers to entrap nZVI and study microbial biodegradation of the polymers used. A soybean-based biopolymer will be the primary focus of this study for removal of Arsenic.

Nanoparticles (mostly iron-based) have been successfully used for groundwater contaminant removal. However, they are agglomerated in aqueous media due to magnetic and Van der waals forces and settle down in the aquifer pores. Surface modification of nanoparticles have been tried using synthetic and plant-based biopolymer within this NDWRRI supported project on “Plant-based Biopolymers for Entrapping Metal Nanoparticles for Arsenic removal: Biodegradation and Treatability Studies”. The project was originally started by a graduate student from Environmental Conservation Sciences and later continued by a former NDWRRI Fellow (Rabiya Shabnam) and two undergraduate students from Civil Engineering under the title “Testing Biodegradation of Polymer Coated Nanoparticles in Aqueous Media”. Biodegradation of synthetic and plant-based polymers in the presence of nanoscale zero-valent iron (NZVI) has been the emphasis of this project. The copolymers developed for NZVI coating by two former NDWRRI fellows (Sita Krajanpan and Harjyoti Kalita) were used in the degradation studies. The results indicate that polysiloxane-polyethylene glycol-carboxylic acid based synthetic copolymers do not degrade easily but degrade faster in the presence of NZVI. A soybean oil based copolymer used in this study showed complete and fast degradation with and without NZVI. This fellowship research has used a new robust method to evaluate biodegradability of polymers and polymer coated NZVI. The new method uses respirometric techniques and acquires biochemical oxygen demand data continuously from the aqueous samples containing polymer or polymer coated NZVI.

Work completed by a former NDWRRI Fellow, Rabiya Shabnam, and two undergraduate students from NDSU Civil Engineering department since Dhritikshama Roy quit the Fellowship early on practically with no contribution to the project.

Temporal-spatial distribution (dynamics) of phytoplankton and diversity in relation to lake physical and chemical condition

Basic Information

Title:	Temporal-spatial distribution (dynamics) of phytoplankton and diversity in relation to lake physical and chemical condition
Project Number:	2011ND240B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	01
Research Category:	Water Quality
Focus Category:	Water Quality, Nutrients, Surface Water
Descriptors:	None
Principal Investigators:	Wei Lin

Publications

1. Veselina Valkov "Temporal-spatial distribution (dynamics) of phytoplankton and diversity in relation to lake physical and chemical condition". Young Professionals poster competition at the North Dakota Water & Pollution Control Conference (NDWPCC), 11-13 October 2011, Bismarck
2. Veseline Valkov (2011) "Temporal-spatial distribution (dynamics) of phytoplankton and diversity in relation to lake physical and chemical condition". Presented at the 5th International Student Prairie Conference, June 2-3, 2011. North Dakota State University, Fargo, ND.
3. Anusha Balangoda, Veselina Valkov, Jinhai Zhao, and Wei Lin (2012) Seasonal Variations of Water Quality and Algal Growth in the Heinrich-Martin Dam Impoundment Presented at the North Dakota Water Quality Monitoring Conference, February 27-29, Bismarck, North Dakota.

Eutrofication as a result of anthropogenic input of nutrients especially phosphorus and nitrogen, that cause real (or perceived) concerns for surface water quality, is significant problem for North Dakota lakes and reservoirs. The increased input of nutrients causes excessive and rapid growth of phytoplankton. Biological productivity is high and the diversity of biological populations may be limited. The massive development of phytoplankton especially Cyanophiceae (blue-green algae), tends to form dense “surface blooms”. Some species are toxic or could cause allergic reaction. Surface blooms reduce light and nutrient availability to other algal species leading to lower algal diversity. High turbidity and floating films (mats) caused by algal blooms reduce light penetration, which is important for photosynthetic activity of submersed macrophytes. Sedimentation dead algae biomass causes increasing of organic matter in the sediments. Decomposition of sediment organic matter causes oxygen depletion, forming anoxic condition at the sediment surface and the deep water fauna becomes deprived of oxygen. Even pelagic fish, which release their eggs in open water to sink to the bottom, cannot continue to reproduce under anoxic sediment surface. Anoxic condition causes change in microbial and chemical processes. The release of nutrients from the anoxic sediments (internal loading) especially phosphorus causes self acceleration of eutrophication. Spectacular fish kill may result from advanced eutrophication. The goal of the proposed project is to expand existing research on water quality of the eutrophic impoundment Henrich Martin Dam. The scope is to understand how variation in physical and chemical disturbances influenced spatial - temporal phytoplankton distribution and diversity and can cause shifts in changes in community patterns.

Two sampling seasons: 6.4-10.15 2010 with aeration and 6.30-8.11 2011, with aeration/non- aeration period. Samples were taken from 5 sites on biweekly basis Physical parameters: Secchi depth, Turbidity, Temperature, DO, pH, Total and volatile suspended solids (TSS ,VSS), Chemical oxygen demand (COD). Chemical parameters – NO_2, NH_4^+, NO_3,Total Nitrogen (TN), Total dissolved nitrogen (TDN), Total Phosphorus(TP), Total dissolved P(DP), Soluble Reactive Phosphorus (SRP) and Total reactive Phosphorus (TRP), Acid hydrolysable Phosphorus. Biological parameters/analyses - Chl a and phytoplankton abundance and speciation.

The water temperature increased steadily with maximum in July after that decreased temporally. The aeration system caused destratification eliminated thermocline. On Julay 13th, 2011 the aeration system was turn off and a week after thermocline was developed between 1 and 2 m. with drop of 3.20 °C. With the depth DO concentration decreases all seasons from super saturated on the surface to close to standard of 5.00 mg/l on the bottom. In 2011 after aeration was stopped concentration of 1.75 mg/l was measured at just 2.00 m and dropped to 0.8 mg/l in deepest layer. That could be correlated with algal accumulation on the surface, diurnal variation in respiration and photosynthesis, microbiological activity, wind mixing, however high organic matter in the water column. Diurnal fluctuation of DO 24 hour’s measurements without aeration shows highest values near the surface between 8-11 p.m. and minimum were observed in the morning’s hours at 6 a.m. The dramatically depleted DO likely caused the observed fish kill, floating decayed biomass, scum and rotten smell on the shallows parts in the lake. The aeration system as short term affect maybe is not efficient to reaches these outlying edges. High density macrophytes as Contail observed at the shallow parts also contribute to the DO balance. COD decreased in depth indicates high consumption of oxygen at the bottom of Site A during non-aerated

period. The algae growth affected transparency of water. The high Secchi depth 1.70 -2.50 m. was contributed to low Chla and TSS and VSS concentrations usually occurred in June 2010/2011. On the June, 18 2010 the transparency decreased rapidly influenced from strong wind that increased TSS and turbidity and high Diatom dominance and Chl a reached 32.89 μg/l (Chla 20-56 μg/l are classified as eutrophic). In July, 13th 2011 observed with necked eye healthy population of Aphanizomenon sp. (Cyanophyceae) aggregates decreased Secchi depth to 1.60 m. Two weeks after stopping aeration system high turbidity reduced the Secchi depth to 0.70 m. The Aphanizomenon aggregates were packed up and population constituted from single filaments. The algae cells that were brought out from upper layer from tabulation slowly migrated and accumulated on the surface and Chl a increased from 32.07 to 79.87 μg/l on A site, while in the bottom the change was less remarkable. Aeration system also affected nutrients variation in depth. During aeration period there were little concentration gradient in nutrients occur in water column. Inorganic nitrogen decreases in the summer remains low. In well oxidized waters, the release of NH4 could be rapidly nitrified to NO3 and further use from phytoplankton. The high values of NH4 were detected late in summer as result of decomposition of prior high growth of algae, high temperatures and low DO. In addition, stopped aeration, very slow mixing, and oxygen depletion increased NH4 in the bottom from 0.04 to 1.08 mg/l just after a month imply high rate of mineralization of organic matter and possible release from sediments. At such low DO concentrations high organic matter in the sediments (about 13%.mesured) is oxidized with NO3 and is reduced to N2. As a controlling algal growth factor SRP varies in concentration fallowing the temporal variation in temperature that affecting oxidation-reduction of Al and Fe exchangeable complexes in the sediments. The high concentrations of SRP 0.05-0.18 mg/l were no limitation factor for phytoplankton growth. No clear correlation was found between the phytoplankton growth and SRP. In 2011 developed thermocline caused increasing concentration in the bottom layers up to 0.47mg/l, which also indicate sediment release as a main source of P in the HMD.

The N limitation, decreased temperature, return to artificial mixing and seasonal turnover effect maybe led to reduced algae abundance, high transparency (Secchi disk = 3.6 m at A site and touched the bottom at C and D site). As result DO levels incased and the NH4 and SRP flux to the overlying surface water was sufficient for phytoplankton growth later in November. The strong N limitation in the summer months in all sampling seasons led to low the N:P ratio. The Redfield ratio 7.5:1 on biomass basis typically evaluated with respect to phytoplankton growth, which is empirically determinate values are needed for growth. Nuisance blue-green algae (Cyanobacteria) blooms are often associated with lakes that have low nitrogen to phosphorus (N:P) ratios.

During study periods, ten classes were identified, dominated of which were Bacillariophyceae, Dinohyceae, Chryptophyceae, Cyanophyceae and Chlorophyceae. The changing in the temperature, duration of the day and nutrient supply led to the succession sequence. At the beginning of June Bacillariophyceae was dominant class in terms of species numbers, density and biomass. Later in summer the Dinophyceae starts to be a dominating class. Class Chrysophyceae haracterizied with occurrence of mixotrophy was found once in June 2010 and in August and September in 2011, probably due to their requirements for high water temperature or nutrition supply. The period between these two dominant classes is characterized with more diversity between groups. Not as expected under

Nitrogen limited condition class Cyanophyceae in 2010 contributed no more than 11% from the total abundance in summer, while in 2011 was 76%, in spite of aeration system still worked. The population of Cyanophyceae tree weeks after aeration was stopped collapsed. Potential explanation include acceleration of buoyancy-induced vertical migration rates, protection against photo inhibition, reduce grazing losses, high oxygen, that could inhibit which could potentially inhibit nitrogenaze activity, exposure to the nutrients and turbulence. The population continued to decrease and replaced by Dinoflagellate.

Ecosystem Services and Wetland Condition Assessment in the Prairie Pothole Region

Basic Information

Title:	Ecosystem Services and Wetland Condition Assessment in the Prairie Pothole Region
Project Number:	2011ND241B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	01
Research Category:	Ecological Processes
Focus Category:	Wetlands, Methods, Non Point Pollution
Descriptors:	None
Principal Investigators:	Edward Dekeyser, Jack Eugene Norland

Publications

1. Meyers, L.M., E.S. DeKeyser, J.E. Norland, C.L.M. Hargiss, and T. DeSutter. 2012. Wetland assessment and ecosystem services. North Dakota Water Quality Monitoring Conference, Bismarck, ND.
2. DeKeyser, E.S., C.L.M. Hargiss, L.M. Meyers, M.J. Ell. 2012. The development of a multiple collaborator venture connected to the National Wetland Condition Assessment in North Dakota. North Dakota Water Quality Monitoring Conference, Bismarck, ND.

This study seeks to assess and evaluate wetlands across the state of North Dakota with a special emphasis on wetlands in the Prairie Pothole Region (PPR). In the summer of 2011, four assessment and nutrient studies were completed on 55 wetlands. The National Wetland Condition Assessment (NWCA) evaluated vegetative, soil, water, algal, hydrological and buffer wetland characteristics. The NWCA not only included intensive sampling of these biological and physical criteria, but also included a rapid assessment of these criteria. Regional wetland assessments developed for North Dakota were also completed at each site. Each wetland was rapidly assessed using the North Dakota Rapid Assessment Method (NDRAM), plant community composition of each wetland was evaluated using the Index of Plant Community Integrity (IPCI), and functional characteristics of the wetlands were evaluated using the Hydrogeomorphic (HGM) model. At each wetland, live plant and soil samples were collected for nutrient analysis.

The final completion NDWRRI report has been submitted and is available on the NDWRRI website.

Bioavailability of Dissolved and Colloidal Organic Carbon Bound Estrogen

Basic Information

Title:	Bioavailability of Dissolved and Colloidal Organic Carbon Bound Estrogen
Project Number:	2011ND242B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	01
Research Category:	Ecological Processes
Focus Category:	Toxic Substances, Water Quality, None
Descriptors:	None
Principal Investigators:	Francis Xavier McKeon Casey

Publications

There are no publications.

The natural estrogen, 17ƒÒ-Estradiol (E2), is the most potent endocrine disrupting compound. The issue of reproductive hormones in the environment is of particular relevance to animal agricultural because of the association of hormone detections with manure management practices. Natural hormone concentrations have been detected in runoff and receiving surface waters as a result of field manure application. Reproductive hormones have also been measured in subsurface waters in proximity to intensive livestock production. Widespread E2 detections throughout the soil profile and shallow groundwater in fields in and around a swine (Sus scrofa domesticus) farm has been found in western North Dakota.

The objectives of this proposed project are the following: (i) Evaluate the association of radiolabeled estradiol with both the Dissolved organic carbon (DOC) and colloidal organic carbon (COC) fraction derived fromliquid swine manure, soil and liquid swine manure applied to soil (ii) Simulate rainfall events to investigate the dislodgment of radiolabeled estradiol from the COC fraction (iii) Evaluate the estrogen potency of estradiol bound to the DOC/COC, DOC and COC fraction using estrogen receptor competitive assays.

1. Preservatives: A preliminary survey of ELISA responses to various preservatives, E2 concentrations, and DOC/COC concentrations has been conducted. There is a potential that the preservative formaldehyde could interfere with the ELISA response. ELISA responses were measured for solutions of formaldehyde (2.5%) and another preservative, sodium azide (0.2%). Also, several concentrations of E2 and dilutions of DOC/COC solution were tested. Appropriate replications and blocks from this first ELISA analysis allowed the use of an ANOVA statistical comparison. The effects from this preliminary

test indicated that COC/DOC (probability (p) = 0.0055), formaldehyde (p= 0.0420) and E2 concentration ($p<0.0001$) were significant in explaining the ELISA response. The conclusions that can be made from these initial results are: (i) Use sodium azide to preserve samples, (ii) The DOC/COC does have a significant effect on spectrometer response of the ELISA (i.e. the more DOC/COC, the greater the overestimation of concentration). However, the 5% and 0.5% COC/DOC concentrations were not significantly different from the solution with no DOC/COC. This may indicate that “yes” the E2 bound to DOC/COC can still interact with the hormone receptors and induce an estrogenic response.

2. E2 Association/Dissociation with COC: The results from the ultrafiltration of the swine lagoon manure spiked with radiolabeled E2 show that E2 is associated with COC partials and that E2 can be dislodged from the COC particles when rinsed with water. The environmental implication of these finding is that E2 can “hitch-hike” on COC partial to be distributed in the environment and be dislodged potentially as free estradiol.

3. E2 Bound to COC is Characteristic of a Particulate: Reverse and normal phase Thin Layer Chromatography (TLC) has been done on the COC fraction of liquid swine manure. The result show that the radiolabelled E2 bound associated with the COC fraction does not behave like a molecule but more as a particle. Specifically, the COC fraction did not respond to chromatographic separation because the radioactivity stayed at the origin of both the normal and reverse phase TLC. This indicates that the 14CE2 associated with the COC is acting like a particle and not like a molecule.

4. E2 Bound to COC is Bioavailable: The results from the Estrogen Receptor (ER) competitive –binding assays show that there is an estrogen response induced by the E2 associated with the COC fraction. The concentrations above the bars in Fig. 5 are the estradiol equivalence derived from the standard curve. These result indicated that estradiol bound to COC still has endocrine disrupting properties and can potentially cause adverse effects to aquatic organisms. The estrogen response from the COC rinses mimics the response of the radiolabeled estradiol experiments. This indicates that estradiol can be carried by COC particles but is loosely bound and can be released into the environment as free estradiol.

Role of agricultural drainage on transport of Cryptosporidium oocysts in North Dakota

Basic Information

Title:	Role of agricultural drainage on transport of Cryptosporidium oocysts in North Dakota
Project Number:	2011ND243B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	01
Research Category:	Water Quality
Focus Category:	Water Quality, Agriculture, Surface Water
Descriptors:	None
Principal Investigators:	Khan Eakalak, John McEvoy

Publications

1. Wadhawan, T., Kasi, M., McEvoy, J., Chu, M., Khan, E. 2012. Investigating transport of Cryptosporidium under snowmelt conditions. World Environmental and Water Resources Congress. Albuquerque, New Mexico, USA.
2. Wadhawan, T., Kasi, M., Chu, M., Khan, E., McEvoy, J. 2012. Bench-scale rainfall and snowfall simulations to understand Cryptosporidium parvum transport in subsurface groundwater regimes. IV International Giardia and Cryptosporidium Conference, Wellington, New Zealand.
3. Wadhawan, T., Kasi, M., McEvoy, J., Chu, M., Khan, E. 2011. Role of Manure Application on Soil in Preventing Groundwater Contamination by Cryptosporidium. 84th Water Environment Federation s Annual Technical Exhibition and Conference, Los Angeles, USA.
4. Wadhawan, T., Khan, E., Chu, X., McEvoy, J. 2011. Adsorption of Cryptosporidium parvum oocyst on soil samples obtained from North Dakota. 2011 Land Grant & Sea Grant National Water Conference, Washington DC, USA.

The sources for Cryptosporidium can be human or animal; however, the understanding of a relationship between the source and disease transmission is limited. A study investigating the degree of strain variation exhibited by bovine and human isolates was conducted on the Red River of the North in 1998. Samples were collected from various parts of the watersheds for the presence of Cryptosporidium and identified 20 different isolates, some of which might cause human infections. Cryptosporidium parvum will be used as a model organism in this project for two reasons. First, the bovine strains of C. parvum were the most common isolates observed. Secondly, C. parvum is the primary cause of human cryptosporidiosis in the region. The main scope of this project is to investigate the role of agricultural drainage system on transport of Cryptosporidium in North Dakota. The specific objectives of this study are: 1) To investigate adsorption

and desorption of Cryptosporidium parvum on the soils obtained from agricultural fields in North Dakota. 2) To determine the effects of agricultural drainage systems on the transport of Cryptosporidium parvum through the soils obtained from agricultural fields in North Dakota by simulating subsurface tile drains in a soil box and 3) To study the transport of Cryptosporidium found in the manure applied to a subsurface drained agricultural field in North Dakota. This research is expected to demonstrate for the first time the role of agricultural drainage system on the transport of Cryptosporidium. It will greatly benefit North Dakota in identifying a possible source of cryptosporidiosis outbreaks.

To achieve objective 1, experiments were designed to investigate adsorption of Cryptosporidium parvum on natural soil by performing isotherm in the presence of manure. High adsorption of Cryptosporidium parvum was observed on both loam and clayey soil. Without manure, very slightly higher adsorption of Cryptosporidium to the clayey soil (1.94 ×105 to 1.75×106) compared to the loam soil (1.92×105 to 1.68×106) was observed. With manure, the adsorption of Cryptosporidium to the rocky sand increased by 35.2%-36.2%, while for the loam and clayey soil, the increases in adsorption were minimal, 2.3%- 2.6% and 1.3%-1.5%, respectively. The high adsorption of the oocysts to soil with or without addition of manure will prevent transport of Cryptosporidium and restrict oocysts to the top soil in the fields. The adsorption onto the rocky sand increased with the addition of manure. Addition of manure to the loam and clayey soil resulted in slight increase in the adsorption of the Cryptosporidium. Good fit of the experimental data to the Freundlich isotherm suggests the role of non-specific physical forces involved in the adsorption of oocysts. The Redlich-Peterson isotherm also gave a good fit to both of the soils. The Redlich-Peterson model fitted the experimental data as good as the Freundlich model. These isotherm results should be useful in drawing inferences for further studies on Cryptosporidium transport.

Objective 2 was achieved by performing soil box experiments. We evaluated the effect of two precipitation conditions with varying intensities and durations on Cryptosporidium parvum transport. The experiments were performed in a soil box with a surface area of 172 cm2. Chloride tracer or C. parvum was applied to the surface of a saturated soil box. Rainfall intensities of 2.5 and 5 cm/h for 1 h duration were simulated using a syringe pump. Conditions were chosen to represent 1 and 10 year rainfall events for Fargo, North Dakota, USA. To simulate snowmelt, the saturated soil box was kept at -20℃ for 24 h, after which 200 g of ice (~116 mL of water) was applied. Two subsurface groundwater

regimes drained the soil box using a drain tile or a small outlet. Both regimes were studied with and without the overland flow. Cryptosporidium was quantified using immunofluorescence microscopy. Our data show that none of the precipitation events could completely drain chloride (Figure 4) or C. parvum (data not shown). The numbers of C. parvum in the effluent varied from 5% to 50% of the influent. This study provides insight into the transport of Cryptosporidium under varying precipitation and subsurface flow conditions.

Co-entrapment of iron nanoparticles and trichloroethylene degrading bacteria in alginate biopolymer for groundwater remediation

Basic Information

Title:	Co-entrapment of iron nanoparticles and trichloroethylene degrading bacteria in alginate biopolymer for groundwater remediation
Project Number:	2011ND244B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	01
Research Category:	Water Quality
Focus Category:	Water Quality, Groundwater, Methods
Descriptors:	None
Principal Investigators:	Achintya Nayan Bezbaruah, Khan Eakalak

Publications

1. Bezbaruah, A.N.; Shanbhogue, S.S.; Simsek, S.; Khan, E. Encapsulation of Iron Nanoparticles in Alginate Biopolymer for Trichloroethylene Remediation, Journal of Nanoparticle Research, 13:6673-6681, 2011.
2. Shanbhogue, S.S.; Simsek , S.; Khan, E.; Bezbaruah, A. Encapsulation of Iron Nanoparticles and Trichloroethylene Degrading Bacteria for Groundwater Clean-up, Proc. World Environmental and Water Resources Congress 2011, pp. 1075-1082, 2011 (also oral presentation)

The focus of this research is on co-entrapment of microorganisms and NZVI to remediate contaminated groundwater. The combined effect of microorganisms and NZVI will increase the degradation efficiency and allow nearly complete degradation of target contaminants. The contaminant chosen to work on is trichloroethylene (TCE), a halogenated aliphatic organic compound and a universal degreasing agent. TCE is a Class A carcinogen and one of the most commonly detected volatile organic chemical in ground water. Bioremediation of TCE is one of the most attractive methods to remove TCE from the environment. The method of bioremediation has been used at an anaerobic aquifer at St. Joseph, Michigan, a TCE contaminated site on the National Priority List (NPL). The study of co-entrapment of NZVI and microorganisms is expected to yield critical conclusions for improving dechlorination reactions. An effective 2-stage remediation process will be engineered with the expectation that the contamination degradation efficiency will increase, reducing the contaminant to its very benign forms. The proposed new method has the potential to satisfy section 121 of CERCLA.

This research focuses on the encapsulation of iron nanoparticles and microorganisms into alginate capsules (reactors). The combined microorganism-metal system can be used for the remediation of environmental contaminants present in groundwater. This system is a good choice because it is a cost effective, environmentally friendly, and can be used to remediate a wide range of contaminants. The interactions between iron nanoparticles and microorganisms have been explored by prior work in our research group. NZVI have been used to remediate a wide range of groundwater contaminants including chlorinated compounds (e.g. TCE). Their small size and high reactive surface area make them highly efficient for contaminated water remediation. However, NZVI particles exhibit high Brownian motion and collide against each other and agglomerate. Agglomeration causes them to sediment out in the aquifer pores and they become unavailable for contaminant remediation. Effective delivery of the NZVI particles is essential to ensure the success of the in-situ remediation process. NZVI can be effectively encapsulated/entrapped in alginate polymer without any significant reduction in their reactivity. The entrapment process reduces the mobility of the NZVI particles and, thus, helps curb the sedimentation problem. The porous nature of Ca-alginate allows solutes to diffuse and come into contact with the entrapped NZVI. Alginate is a very extensively used as surface modifier for NZVI. Furthermore bacterial cells encapsulated within calcium alginate have been used extensively for environmental remediation.

The main objective of this study is the co-entrapment of NZVI and TCE degrading bacteria in alginate polymer to achieve complete degradation of TCE in groundwater.

Alginate capsules have been synthesized and NZVI was successfully encapsulated. Diffusion and treatability studies using encapsulated NZVI were performed for varying concentrations of TCE. Microorganisms were encapsulated and used for TCE degradation. Encapsulated NZVI, microorganisms, and the combined metal-microorganism system were found to be effective for TCE degradation. The project is on-going using different strains of microbes to test the efficacy of the combined metal-microorganism system. Based on the progress made so far a manuscript was submitted to a peer reviewed journal.

Information Transfer Program Introduction

Information dissemination is done through an annual newsletter, and presentations and publications by grant and fellowship recipients. A web site also helps disseminating institute research information. The institute's website address is http://www.ndsu.edu/wrri. Past newsletters can be accessed through the institute web site. Technical reports of Fellowship projects authored by the Fellows and advisers are also placed on the institute web site. Institute also sponsoring and/or co-sponsors local and state confernces and seminars. A Distinguished Water Seminar by an eminent water expert/professional is an annual event conducted by NDWRRI.

Information Dissemination and Communication

Basic Information

Title:	Information Dissemination and Communication
Project Number:	2009ND175B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	01
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	G. Padmanabhan

Publications

There are no publications.

Activities to disseminate institute and other research under this project included:

1. Maintaining a web site
2. Publishing a newsletter
3. Publication of Fellowship and other research done through the Institute
4. Presentation of research results to state and federal water agencies
5. Sponsor or co-sponsor local or regional conferences

The website of the Institute was updated at least quarterly, and more often when a research project wished to provide updates or when a Fellow graduates. The website provides additional details on the research. The list of Institute Affiliate Faculty with their expertise was updated. Research reports published by the institute were placed on this web site as and when they became available. The institute web site is

http://www.ndsu.edu/wrri.

The Institute continued its annual newsletter, which highlights the graduate research fellowship program, the research grants associated with it, and general summaries of ongoing research. The newsletter profiled institute research and researchers and published other newsworthy water issues in the State

The Institute continued its efforts to enhance communication between the State and Federal agency personnel and university faculty and students. Advisors and fellows presented their research results to State and Federal professionals in Bismarck. The Institute also encouraged its Fellows and faculty to attend seminars and conferences held in the region. Modest support for travel was provided by the institute whenever appropriate.

The Institute continued to work toward establishing the Institute as a clearinghouse for information on water resources research expertise of faculty and staff at NDSU and UND.

Information Dissemination and Communication

Basic Information

Title:	Information Dissemination and Communication
Project Number:	2011ND233B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	G. Padmanabhan

Publications

There are no publications.

Activities to disseminate institute and other research under this project included:

1. Maintaining a web site
2. Publishing a newsletter
3. Publication of Fellowship and other research done through the Institute
4. Presentation of research results to state and federal water agencies
5. Sponsor or co-sponsor local or regional conferences
6. Sponsor special lectures on water-related topics of interest

The website of the Institute was updated at least quarterly, and more often when a research project wished to provide updates or when a Fellow graduates. The website provides additional details on the research. The list of Institute Affiliate Faculty with their expertise was updated. Research reports published by the institute were placed on this web site as and when they became available. The institute web site:

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NDWRRI 2nd Annual Distinguished Water Seminar

The NDWRRI 2nd Annual Distinguished Water Seminar was held on February 21, 2012 at NDSU campus open to faculty and students of NDSU and UND and the public. Dr. Kurt Fausch, a nationally and internationally known conservation biologist, conducted the seminar titled, " Linked for Life: the importance of sustaining hidden connections for conservation in streams." The talk was co-sponsored by the the Environmental and Conservation Sciences program, Agricultural and Biosystems Engineering department, Civil Engineering department, Soil Science department, and School of Natural Resources Sciences and Management, all of North Dakota State University. The seminar is the second of the annual Distinguished Water Seminar series by eminent water professionals on emerging issues, challenges and new research directions in water resources.

Dr. Fausch is a professor in the Department of Fish, Wildlife, and Conservation Biology at Colorado State University. He teaches Fish Conservation Biology and a graduate course in Community Ecology, and is active in the Graduate Degree Program in Ecology. His collaborative research has taken him worldwide, and especially to Hokkaido in northern Japan where he worked with colleagues over a 15-year period. These experiences were chronicled in the documentary film RiverWebs, directed and produced by Jeremy Monroe of Freshwaters Illustrated, which has been broadcast to more than100 million homes nationwide on PBS. He has received several prestigious awards for his research and outreach, including the first International Fisheries Science Prize from the World Council of Fisheries Societies (2008) and Awards of Excellence from the American Fisheries Society (2010). He serves on the Independent Science Advisory Board of the Northwest Power and Conservation Council, which advises managers of the Columbia River about fish and wildlife conservation. Kurt is currently writing a book for a popular audience with the goal of engaging the public in understanding the interconnections between streams and rivers and their landscapes, and the importance of conserving these ecosystems.

Following the seminar, students and faculty interacted with Dr. Fausch.

G. Padmanabhan, Director NDWRRI, Craig Stockwell, Director Environmental and Conservation Sciences Graduate Program, and Xuefeng Chu, Civil Engineering department were the organizing committee members.

NDWRRI partnered with ND Department of Health, USGS, ND State Water Commission in organizing the ND Water Quality Monitoring Conference February 27-29, 2012 in Bismarck, North Dakota

NDWRRI director, Dr. G. Padmanabhan, participated in the planning as a planning committee member. He encouraged several institute affiliate faculty and NDWRRI Graduate Fellows to participate in the planning and to present at the conference. Dr. Padmanabhan also moderated a session titled "Emerging Contaminants and Threats to Water Quality". Seven past and current NDWRRI Fellows and eight institute affiliate faculty presented and participated at the conference.

Detailed agenda of the conference can be viewed at: http://info.bismarckstate.edu/ceti/waterquality/

Presentation abstracts can be viewed at
http://info.bismarckstate.edu/ceti/waterquality/pdfs/presentation-abstracts.pdf

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	3	0	0	0	3
Ph.D.	6	0	0	0	6
Post-Doc.	0	0	0	0	0
Total	9	0	0	0	9

Notable Awards and Achievements

Publications from Prior Years

1. 2009ND184B ("Polymer Modified Zero-valent Iron Nanoparticles for Arsenic Remediation: Longevity and Ionic") - Conference Proceedings - Krajangpan, S.; Bezbaruah, A.N.; Chisholm, B.J. Groundwater Arsenic Remediation using Amphiphilic Polysiloxane Graft Copolymer Coated Iron Nanoparticles, Proc. World Environmental and Water Resources Congress 2011, pp. 1083-1088, 2011 (also oral presentation).
2. 2009ND187B ("Interactions Between Microorganisms and Metal Nanoparticles: A New Approach for Groundwater Remediation (Final Phase)") - Conference Proceedings - Shabnam, R.; Simsek , S.; Khan, E.; McEvoy, J.; Bezbaruah, A. Diffusion and Treatability Studies with Biopolymer Encapsulated Zero-valent Iron Nanoparticles, Proc. World Environmental and Water Resources Congress 2011, pp. 1543-1551, 2011(also oral presentation).
3. 2009ND188B ("Ion Imprinted Polymer for Removal and Monitoring of Arsenic (Phase II)") - Conference Proceedings - Kalita, H.; Chisholm, B.; Bezbaruah, A.N. Novel Arsenic Ion-imprinted Polymer: Simultaneous Removal As(III) and As(V) from Water, Proc. World Environmental and Water Resources Congress 2011, pp. 3396-3401, 2011 (also oral presentation).
4. 2009ND186B ("Development of GAC-NZVI Adsorbent for Arsenic Removal") - Dissertations - Chang, Qigang, Ph.D., Environmental and Conservation Sciences Program, College of Graduate and Interdisciplinary Studies, North Dakota State University, August 2011. Iron-Impregnated Granular Activated Carbon for Arsenic Removal from Drinking Water. Major Professor: Dr. Wei Lin.
5. 2010ND214B ("Reference Evapotranspiration and Actual Evapotranspiration Measurements in ND") - Dissertations - Ishara Rijal, M.S., Agricultural and Biosystems Engineering, College of Engineering and Architecture, North Dakota State University, August 2011. Reference Evaporation and Actual Evaporation Measurements in Southeastern North Dakota. Major Professor: Dr. Jia Xinhua.
6. 2010ND211B ("The Impact of Rural and Urban Flooding on Water and Soil Quality in the Red River Valley of the North") - Water Resources Research Institute Reports - Effects of Major Flooding on Water and Sediment Characteristics in an Urban Environment, Adam Guy and Thomas DeSutter, Department of Soil Science, NDSU, NDWRRI report ND11-01, June 2011.
7. 2009ND189B ("Chemical Fingerprinting of Sediments and Water of the Souris River for Identification of Diffuse Pollution Sources II") - Dissertations - Wijeyaratne, Dimuthu Nilmini, Ph.D., Program of Environmental and Conservation Sciences, College of Graduate and Interdisciplinary Studies, North Dakota State University, March 2011. Multi-element Fingerprinting of River Sediments to Identify Diffuse Pollution Sources. Major Professor: Dr. Marinus Otte.
8. 2010ND211B ("The Impact of Rural and Urban Flooding on Water and Soil Quality in the Red River Valley of the North") - Dissertations - Guy, Adam Christopher, M.S., Department of Soil Science, College of Agriculture, Food Systems, and Natural Resources, North Dakota State University, May 2011. Effects of Major Flooding on Water and Sediment Characteristics in an Urban Environment. Major Professor: Dr. Thomas DeSutter.
9. 2009ND187B ("Interactions Between Microorganisms and Metal Nanoparticles: A New Approach for Groundwater Remediation (Final Phase)") - Dissertations - Rabiya Shabnam, M.S., Environmental and Conservation Sciences Program, College of Graduate and Interdisciplinary Studies, North Dakota State University, August 2011. Interactions of iron nanoparticles with microorganisms. Major Professor: Dr. Achintya Bezbaruah.
10. 2010ND215B ("Uptake and effects of environmental estrogens on growth of fish") - Conference Proceedings - Hanson, A. and Sheridan, M.A. Effects of Environmental Estrogens on Organismal Growth and the Growth Hormone-Insulin-Like-Growth Factor System of Rainbow Trout. Annual Meeting of the Society for Integrative and Comparative Biology, Salt Lake City, UT, January 4-7, 2011.
11. 2010ND215B ("Uptake and effects of environmental estrogens on growth of fish") - Other Publications - Hanson, A. and Sheridan M.A. Environmental Estrogens Inhibit the Expression of

Insulin-like Growth Factors 1 and 2 in the Liver and Gill of Rainbow Trout in vitro. Presented at the Annual Meeting of the Society for Integrative and Comparative Biology, Charleston, SC, January 3-7, 2012.

12. 2010ND215B ("Uptake and effects of environmental estrogens on growth of fish") - Articles in Refereed Scientific Journals - Hanson, A., Kittilson, J.D., McCormick, S.D., Sheridan, M.A., 2011. Effects of 17â-estradiol, 4- nonylphenol, and â-sitosterol on the growth hormone-insulin-like growth factor system and seawater adaptation of rainbow trout (Oncorhynchus mykiss). Aquaculture, in press.